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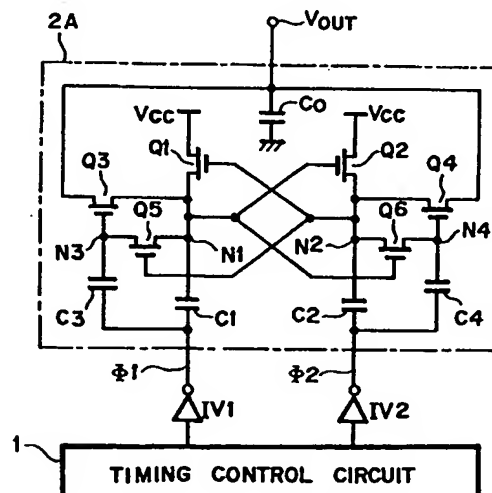
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### (54) Boost voltage generating circuit.

(57) A boost voltage generating circuit includes a boost voltage producing circuit (2) having a first and a second capacitor receiving a first and a second control signal, respectively, a third smoothing capacitor ( $C_1, C_2, C_0$ ) connected at an output terminal ( $V_{OUT}$ ), and a first, a second, a third, and a fourth transistor ( $Q_1, Q_2, Q_3, Q_4$ ). A boost output voltage is derived through the third and fourth transistors. The boost voltage producing circuit (2) further includes a fourth capacitor ( $C_3$ ) connected between the first capacitor ( $C_1$ ) and the gate of the third transistor ( $Q_3$ ); a fifth capacitor ( $C_4$ ) connected between the second capacitor ( $C_2$ ) and the gate of the fourth transistor ( $Q_4$ ); a fifth transistor ( $Q_5$ ) having one of a source and a drain connected to the first capacitor ( $C_1$ ) with the other thereof connected to the gate of the third transistor ( $Q_3$ ) and a gate connected to the second capacitor ( $C_2$ ); and a sixth transistor ( $Q_6$ ) having one of a source and a drain connected to the second capacitor ( $C_2$ ) with the other thereof connected to the gate of the fourth transistor ( $Q_4$ ) and a gate connected to the first capacitor ( $C_1$ ). The arrangement enables to maintain the gate potential of the third and fourth transistors ( $Q_3, Q_4$ ) above a predetermined level, thereby preventing the lowering

of current driving capability of these transistors and the lowering of current supplying capability for a boost potential.

FIG. 2A



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## BACKGROUND OF THE INVENTION

### (1) Field of the Invention

The present invention relates to a boost voltage generating circuit, and more particularly to a boost voltage generating circuit for producing a boost potential for a word line of a semiconductor memory device or of a substrate potential for a semiconductor integrated circuit.

### (2) Description of the Related Art

An example of the conventional boost voltage generating circuit of the kind to which the present invention relates is shown in Fig. 1A and the waveforms obtained at various points therein are shown in Fig. 1B.

The conventional boost voltage generating circuit referred to above is constituted by a timing control circuit 1 and a boost voltage producing section 2. The timing control circuit 1 outputs a first control signal  $\Phi 1$  and a second control signal  $\Phi 2$  respectively through an output node of an inverter IV1 and an output node of an inverter IV2. The first control signal  $\Phi 1$  becomes a power supply potential ( $V_{CC}$ ) level and a reference potential (ground potential) level in a predetermined cycle, and the second control signal  $\Phi 2$  becomes a power supply potential level for a predetermined period within the period of the reference potential level of the first control signal  $\Phi 1$  and becomes a reference potential level outside the period of the power supply potential level. The boost voltage producing section 2 includes first and second capacitor elements C1 and C2 which receive respectively the first and second control signals  $\Phi 1$  and  $\Phi 2$  at their first ends; a first N-channel field effect transistor Q1 in which one of a source and a drain is connected to the power supply potential terminal ( $V_{CC}$ ), the other of the source and the drain is connected to a second end of the first capacitor element C1, and a gate is connected to the second end of the second capacitor element C2; a second N-channel transistor Q2 in which one of a source and a drain is connected to the power supply potential terminal  $V_{CC}$ , the other of the source and the drain is connected to the second end of the second capacitor element C2, and a gate is connected to the second end of the first capacitor element C1; a third N-channel transistor Q3 in which one of a source and a drain, and a gate are connected to the second end of the first capacitor element C1, and the other of the source and the drain is connected to a boost potential output terminal  $V_{OUT}$  - ( $V_{OUT}$  also representing the boost potential); a fourth N-channel transistor Q4 in which one of a source and a drain, and a gate are connected to

the second end of the second capacitor element C2, and the other of the source and the drain is connected to the boost potential output terminal  $V_{OUT}$ ; and a third capacitor element  $C_0$  having a large capacitance which is connected between the boost potential output terminal  $V_{OUT}$  and the reference potential terminal.

The operation of the above explained boost voltage generating circuit is as follows.

When the control signal  $\Phi 1$  is at the power supply potential level  $V_{CC}$  and the control signal  $\Phi 2$  is at the ground potential level (0 V), the transistor Q2 turns ON so that the node N2 at the second end of the second capacitor element C2 is charged and becomes the power supply potential  $V_{CC}$ . Also, if the node N1 at the second end of the first capacitor element C1 is at a level higher than  $V_{OUT} + V_T$  ( $V_T$  being the threshold voltage of the transistor), the current flows from the node N1 to the boost potential output terminal  $V_{OUT}$  through the transistor Q3 and thus the boost potential  $V_{OUT}$  is raised to a level higher than the power supply potential  $V_{CC}$ .

Next, contrary to the above, when the control signal  $\Phi 1$  turns to the ground potential level and the control signal  $\Phi 2$  turns to the power supply potential level, the potential at the node N2 rises close to  $2V_{CC}$  whereby the transistor Q1 becomes ON and the node N1 is charged up to the level of the power supply potential  $V_{CC}$ . Also, the charges are supplied to the boost potential output terminal  $V_{OUT}$  through the transistor Q4.

The above operation is repeated and, after being smoothed by the capacitor element  $C_0$  having a large capacitance, the boost voltage  $V_{OUT}$  is raised to a potential higher than the power supply potential  $V_{CC}$ .

The boost voltage  $V_{OUT}$  thus obtained is used for such purposes as for select-level driving of word lines of a semiconductor memory device. Also, when the P-channel transistors are employed and the potentials at various points are reversed, it is possible to obtain the substrate potential to be applied to the substrate of a semiconductor integrated circuit.

In the boost voltage generating circuit described above, since the charges of the capacitor element C1 are supplied to the boost potential output terminal  $V_{OUT}$  through the transistor Q3 when the control signal  $\Phi 1$  is at the power supply potential level  $V_{CC}$ , the level at the node N1 gradually lowers starting from about  $2V_{CC}$  as shown in Fig. 1B. Therefore, the ON-resistance of the transistor Q3 whose gate is directly connected to the node N1 becomes greater, resulting in the lowering of the current driving capability so that, although it is possible to boost the boost potential  $V_{OUT}$  almost to  $2V_{CC}$  minus  $V_T$ , the current supply capability

largely drops once the boost potential  $V_{OUT}$  is set to a high level.

## SUMMARY OF THE INVENTION

It is, therefore, an object of the invention to overcome the problems existing in the prior art and to provide an improved boost voltage generating circuit in which the current supply capability for boost voltage potentials is enhanced.

According to one aspect of the invention, there is provided a boost voltage generating circuit having a timing control circuit and a boost voltage producing circuit, the timing control circuit being for generating a first control signal to become a power supply potential level and a reference potential level at a predetermined cycle and a second control signal to become the power supply potential level during a predetermined period within a period of the reference potential level of the first control signal and become the reference potential level during a period outside the period of the reference potential level, the boost voltage producing circuit including a first and a second capacitor element receiving respectively at their first ends the first and second control signals, a first transistor having either a source or a drain connected to a power supply potential node with the other of the source and the drain connected to a second end of the first capacitor element and a gate connected to a second end of the second capacitor element, a second transistor having either a source or a drain connected to the power supply potential node with the other of the source and the drain connected to the second end of the second capacitor element and a gate connected to the second end of the first capacitor element, a third transistor having either a source or a drain connected to the second end of the first capacitor element with the other of the source and the drain connected to a boost potential output terminal, a fourth transistor having either a source or a drain connected to the second end of the capacitor element with the other of the source and the drain connected to the boost potential output terminal, and a third capacitor element connected between the boost potential output terminal and a reference potential node, the boost voltage producing circuit further comprising:

a fourth capacitor element connected between the first end of the first capacitor element and the gate of the third transistor;

a fifth capacitor element connected between the first end of the second capacitor element and the gate of the fourth transistor;

a fifth transistor having either a source or a drain connected to the second end of the first capacitor element with the other of the source and the drain connected to the gate of the third transi-

tor and a gate connected to the second end of the second capacitor element; and

a sixth transistor having either a source or a drain connected to the second end of the second capacitor element with the other of the source and the drain connected to the gate of the fourth transistor and a gate connected to the second end of the first capacitor element.

## BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present invention will be apparent from the following description of preferred embodiments of the invention explained with reference to the accompanying drawings, in which:

Fig. 1A is a circuit diagram showing a conventional boost voltage generating circuit and Fig. 1B is a chart showing operating waveforms at various points therein;

Fig. 2A is a circuit diagram showing a boost voltage generating circuit of a first embodiment according to the invention and Fig. 2B is a chart showing operating waveforms at various points therein;

Fig. 3A is a circuit diagram showing a boost voltage generating circuit of a second embodiment according to the invention and Fig. 3B is a chart showing operating waveforms at various points therein; and

Fig. 4A is a circuit diagram showing a boost voltage generating circuit of a third embodiment according to the invention and Fig. 4B is a chart showing operating waveforms at various points therein.

## PREFERRED EMBODIMENTS OF THE INVENTION

Now, explanation is made of preferred embodiments of the invention with reference to the accompanying drawings. It should be noted that, throughout the explanation, similar reference symbols or numerals refer to the same or similar elements in all the figures of the drawings.

Fig. 2A shows in circuit diagram a first embodiment of the invention and Fig. 2B shows operating waveforms at various points in the circuit of the first embodiment.

The differences in the boost voltage generating circuit of this embodiment as compared with the conventional circuit shown in Figs. 1A and 1B reside in the provision of a fourth capacitor element C3, a fifth capacitor element C4, a fifth field effect transistor Q5, and a sixth field effect transistor Q6. The fourth capacitor element C3 is connected between the first end of the first capacitor element C1 and the gate of the third transistor Q3. The fifth

capacitor element C4 is connected between the first end of the second capacitor element C2 and the gate of the fourth transistor Q4. As to the fifth transistor Q5, one of a source and a drain is connected to the second end of the first capacitor element C1, the other of the source and the drain is connected to the gate of the third transistor Q3, and a gate is connected to the second end of the second capacitor element C2. As to the sixth transistor Q6, one of a source and a drain is connected to the second end of the second capacitor element C2, the other is connected to the gate of the fourth transistor Q4, and a gate is connected to the second end of the first capacitor element C1.

Next, the operation of the circuit according to this embodiment is explained.

When the control signal  $\Phi 1$  turns to the power supply potential level  $V_{CC}$  and the control signal  $\Phi 2$  turns to the ground potential level, the node N1 and the node N3 rise almost to  $2V_{CC}$  so that the transistor Q3 turns ON and thus the current flows from the node N1 to the boost potential output terminal  $V_{OUT}$ . Thus, although the potential at the node N1 gradually drops, the node N3 continues to maintain a high potential because the transistor Q5 is in an ON state. Also, the transistor Q6 is in an ON state, so that the gate of the transistor Q4, that is, the node N4 are precharged to the potential at the node N2 with a consequence that the transistor Q4 is turned OFF. Next, when the control signal  $\Phi 1$  turns to the ground potential level and the control signal  $\Phi 2$  turns to the power supply potential level, the transistor Q1 is caused to turn ON and the node N1 is charged up to the power supply potential  $V_{CC}$ , the transistor Q5 turns ON, the node N3 is precharged to a potential which equals that at the node N1, and the transistor Q3 turns OFF. Further, since the potentials at the node N2 and the node N4 have risen to approximately  $2V_{CC}$  and the transistor Q4 turns ON, the current is supplied to the power supply potential terminal  $V_{CC}$  from the node N2 so that, although the potential of the node N2 gradually drops, it should be noted that the node N4 is maintained at the high potential.

As explained above, even when the potential drops due to the current flow from the nodes N1 and N2 to the boost potential output terminal  $V_{OUT}$ , the gate potentials of the transistor Q3 and the transistor Q4 are maintained at high potentials, whereby the possibility of lowering the current driving capability is minimized and the current supplying capability is significantly increased.

Fig. 3A is a circuit diagram showing a boost voltage generating circuit according to the second embodiment of the invention and Fig. 3B is a diagram showing operating waveforms at various points in the circuit. In the above explained first embodiment, at the timings  $t1$  and  $t2$  in Fig. 2B,

there is a possibility that the currents may momentarily flow in a reverse direction from the boost potential output terminal  $V_{OUT}$  to the nodes N1 and N2 respectively through the transistors Q3 and Q4. This results in wasting power dissipation. The second embodiment of the invention is intended to solve this problem.

According to this second embodiment, the timing control circuit 1A generates through inverters IV3 and IV4 a third control signal  $\Phi 3$  and a fourth control signal  $\Phi 4$  in addition to the first and second control signals  $\Phi 1$  and  $\Phi 2$ . This second embodiment is different from the first embodiment in that the first ends of the fourth and fifth capacitor elements C3 and C4 receive the third and fourth control signals  $\Phi 3$  and  $\Phi 4$ , respectively, in place of the first and second control signals  $\Phi 1$  and  $\Phi 2$ . The control signal  $\Phi 3$  turns to a power supply potential level after the level of the first control signal  $\Phi 1$  becomes the power supply potential level, and turns to a ground potential level before the level of the first control signal  $\Phi 1$  becomes the ground potential level. The control signal  $\Phi 4$  turns to the power supply potential level after the level of the second control signal  $\Phi 2$  becomes the power supply potential level and turns to the ground potential level before the level of the second control signal  $\Phi 2$  becomes the ground potential level. The above third control signal  $\Phi 3$  is supplied to the first end of the fourth capacitor element C3, which end is separated from the first end of the first capacitor element C1 in the first embodiment shown in Fig. 2A. In the same manner, the fourth control signal  $\Phi 4$  is supplied to the first end of the fifth capacitor element C4, which end is separated from the first end of the second capacitor element C2 in the first embodiment shown in Fig. 2A.

Consequently, when the transistor Q3 turns ON, the level at the node N1 definitely becomes the power supply potential level and, when the transistor Q4 turns ON, the level of the node N4 definitely becomes the power supply potential level. Thus, it is possible to prevent the reverse flow of the current from the boost potential output terminal  $V_{OUT}$  to the nodes N1 and N2, so that there is no waste of power unlike in the first embodiment shown in Fig. 2A.

Fig. 4A diagrammatically shows a boost voltage generating circuit of a third embodiment according to the invention, and Fig. 4B shows operating waveforms at various points in such circuit.

In the circuits of the first and second embodiments, the gate level of each of the transistors Q3 and Q4 when it turns ON is in the order of  $2V_{CC}$ . Strictly speaking, the gate level is lower than  $2V_{CC}$  by the potential which is determined by the ratio between the capacitance of each of the capacitor elements C3, C4 and the gate capacitance of each

of the transistors Q3, Q4. As the capacitance of the capacitor elements C3 and C4 increases from the gate capacitance of each of the transistors Q3 and Q4, the gate potential or level will become closer to  $2V_{CC}$ . However, the boost voltage  $V_{OUT}$  will be, even at its maximum, a voltage lower by the threshold voltage  $V_T$  of the transistor than a voltage at the state when the gate potential of the transistors Q3 and Q4 is at the power supply potential. This means that the gate level can be raised only close to  $(2V_{CC} - V_T)$ . The circuit of the third embodiment has improved this point, whereby the gate potential can be raised at the maximum up to almost  $2V_{CC}$ .

The circuit of the third embodiment is provided with level conversion circuits 3a and 3b in addition to the circuit configuration of the second embodiment shown in Fig. 3A. These level conversion circuits 3a and 3b generate respectively a level-converted third control signal  $\Phi_{3a}$  and a level-converted fourth control signal  $\Phi_{4a}$  of high levels in which the power supply potential levels of the third control signal  $\Phi_3$  and the fourth control signal  $\Phi_4$  are made higher respectively by predetermined levels. Each of these high level third and fourth control signals  $\Phi_{3a}$  and  $\Phi_{4a}$  is inputted to the corresponding first end of the fourth and fifth capacitor elements C3 and C4.

The control signals  $\Phi_{3a}$  and  $\Phi_{4a}$  are produced by buffering the outputs from the timing control circuit 1A at the level conversion circuits 3a and 3b. At this time, the boost voltage potential  $V_{OUT}$  is inputted to the level conversion circuits 3a and 3b as an output power supply, whereby the levels of the control signals  $\Phi_{3a}$  and  $\Phi_{4a}$  become boosted voltage levels and thus the high levels at the nodes N3 and N4 rise almost to  $(V_{CC} + V_{OUT})$ . Since the gate levels of the transistors Q3 and Q4 can be raised to the levels higher than those in the circuits of the first and second embodiments, the current driving capability of the transistors Q3 and Q4 becomes large allowing the boost voltage potential  $V_{OUT}$  to rise close to  $2V_{CC}$  at the maximum.

As explained above, according to the invention, the gate potential levels of the third and fourth transistors are maintained above the predetermined levels by the provision of the fifth and sixth transistors and the fourth and fifth capacitor elements. This enables to prevent the lowering of the current driving capability of the third and fourth transistors and also to prevent the lowering of the current supplying capability for the boost potential, which results in the following advantages:

(1) Where the current supply required is the same as that in the prior art, the size of each of the transistors and the capacitor elements can be made smaller so that, in designing a circuit, the area to be occupied by the circuit can be

reduced.

(2) By making the size of each transistor smaller, the current for driving the circuit can be reduced and the current conversion efficiency  $[= (\text{current supplied to } V_{OUT})/(\text{current dissipation from } V_{CC})]$  can be enhanced.

While the invention has been described in its preferred embodiments, it is to be understood that the words which have been used are words of description rather than limitation and that changes within the purview of the appended claims may be made without departing from the true scope and spirit of the invention in its broader aspects.

## Claims

1. A boost voltage generating circuit having a timing control circuit (1;1A) and a boost voltage producing circuit (2A;2B;2C), said timing control circuit (1) being for generating a first control signal ( $\Phi_1$ ) to become a power supply potential level ( $V_{CC}$ ) and a reference potential level at a predetermined cycle and a second control signal ( $\Phi_2$ ) to become said power supply potential level during a predetermined period within a period of said reference potential level of said first control signal and become said reference potential level during a period outside said period of said reference potential level, said boost voltage producing circuit (2A;2B;2C) including a first and a second capacitor element (C1,C2) receiving respectively at their first ends said first and second control signals ( $\Phi_1,\Phi_2$ ), a first transistor (Q1) having either a source or a drain connected to a power supply potential node with the other of said source and said drain connected to a second end of said first capacitor element (C1) and a gate connected to a second end of said second capacitor element (C2), a second transistor (Q2) having either a source or a drain connected to said power supply potential node with the other of said source and said drain connected to the second end of said second capacitor element (C2) and a gate connected to the second end of said first capacitor element (C1), a third transistor (Q3) having either a source or a drain connected to the second end of said first capacitor element (C1) with the other of said source and said drain connected to a boost potential output terminal ( $V_{OUT}$ ), a fourth transistor (Q4) having either a source or a drain connected to the second end of said capacitor element (C2) with the other of said source and said drain connected to said boost potential output terminal, and a third capacitor element ( $C_0$ ) connected between said boost potential output terminal and a ref-

erence potential node, said boost voltage producing circuit (2A) characterized by further comprising:

a fourth capacitor element (C3) connected between the first end of said first capacitor element (C1) and the gate of said third transistor (Q3);

a fifth capacitor element (C4) connected between the first end of said second capacitor element (C2) and the gate of said fourth transistor (Q4);

a fifth transistor (Q5) having either a source or a drain connected to the second end of said first capacitor element (C1) with the other of said source and said drain connected to the gate of said third transistor (Q3) and a gate connected to the second end of said second capacitor element (C2); and

a sixth transistor (Q6) having either a source or a drain connected to the second end of said second capacitor element (C2) with the other of said source and said drain connected to the gate of said fourth transistor (Q4) and a gate connected to the second end of said first capacitor element (C1).

2. A boost voltage generating circuit according to claim 1, wherein said timing control circuit (2B,2C) is for generating, in addition to said first and second control signals ( $\Phi 1, \Phi 2$ ), a third control signal ( $\Phi 3$ ) which turns to a power supply potential level after said first control signal becomes a level of the power supply potential and turns to a level of said reference potential before said first control signal becomes the reference potential level, and a fourth control signal ( $\Phi 4$ ) which turns to the power supply potential level after said second control signal becomes the power supply potential level and turns to the reference potential level before said second control signal becomes the reference potential level, and wherein a first end of said fourth capacitor element (C3) is separated from said first end of said first capacitor element (C1) and receives said third control signal ( $\Phi 3$ ) and a first end of said fifth capacitor element (C4) is separated from said first end of said second capacitor element (C2) and receives said fourth control signal ( $\Phi 4$ ).
3. A boost voltage generating circuit according to claim 2, further comprising a first level conversion circuit (3a) which converts the power supply potential level of said third control signal ( $\Phi 3$ ) into a level-converted third control signal ( $\Phi 3a$ ) with a level higher by a predetermined level and a second level conversion circuit

(3b) which converts the power supply potential level of said fourth control signal ( $\Phi 4$ ) into a level-converted fourth control signal ( $\Phi 4a$ ) with a level higher by a predetermined level, said level-converted third control signal ( $\Phi 3a$ ) being inputted to the first end of said fourth capacitor element (C3) and said level-converted fourth control signal ( $\Phi 4a$ ) being inputted to the first end of said fifth capacitor element (C4).

4. A boost voltage generating circuit according to claim 1, wherein said first through sixth transistors ( $\Phi 1$  through Q6) are N-channel field effect transistors.
5. A boost voltage generating circuit characterized by comprising:
  - a first, a second, a third and a fourth input terminal receiving a first ( $\Phi 1$ ), a second ( $\Phi 2$ ), a third ( $\Phi 3$ ) and a fourth timing control signal ( $\Phi 4$ ), respectively;
  - an output terminal ( $V_{OUT}$ );
  - a first (N1), a second (N2), a third (N3) and a fourth circuit node (N4);
  - a power terminal ( $V_{CC}$ );
  - a first transistor (Q1) having a gate connected with said second circuit node, and a source and a drain coupled between said power terminal and said first circuit node;
  - a second transistor (Q2) having a gate connected with said first circuit node, and a source and a drain coupled between said power terminal and said second circuit node;
  - a third transistor (Q3) having a gate connected with said third circuit node, and a source and a drain coupled between said first circuit node and said output terminal;
  - a fourth transistor (Q4) having a gate connected with said fourth circuit node, and a source and a drain coupled between said second circuit node and said output terminal;
  - a fifth transistor (Q5) having a gate connected with said second circuit node, and a source and a drain coupled between said first and said third circuit nodes;
  - a sixth transistor (Q6) having a gate connected with said first circuit node, and a source and a drain coupled between said second and said fourth circuit nodes;
  - a first capacitor (C1) coupled between said first input terminal and said first circuit node;
  - a second capacitor (C2) coupled between said second input terminal and said second circuit node;
  - a third capacitor (C3) coupled between said third input terminal and said third circuit node; and
  - a fourth capacitor (C4) coupled between

said fourth input terminal and said fourth circuit node.

6. A boost voltage generating circuit according to claim 5, wherein said first and said third input terminals are connected each other and said first and said third timing control signals ( $\Phi 1, \Phi 3$ ) have the same waveform, and said second and said fourth input terminals are connected each other and said second and said fourth timing control signals ( $\Phi 2, \Phi 4$ ) have the same waveform.
7. A boost voltage generating circuit according to claim 5, wherein said first and said third input terminals are separated and said first and said third timing control signals ( $\Phi 1, \Phi 3$ ) have waveforms synchronized each other, and said second and said fourth input terminals are separated and said second and said fourth timing control signals ( $\Phi 2, \Phi 4$ ) have waveforms synchronized each other.
8. A boost voltage generating circuit according to claim 7, wherein levels of said third and said fourth timing control signals ( $\Phi 3, \Phi 4$ ) are boosted to levels higher than those of said first and said second timing control signals ( $\Phi 1, \Phi 2$ ), respectively.

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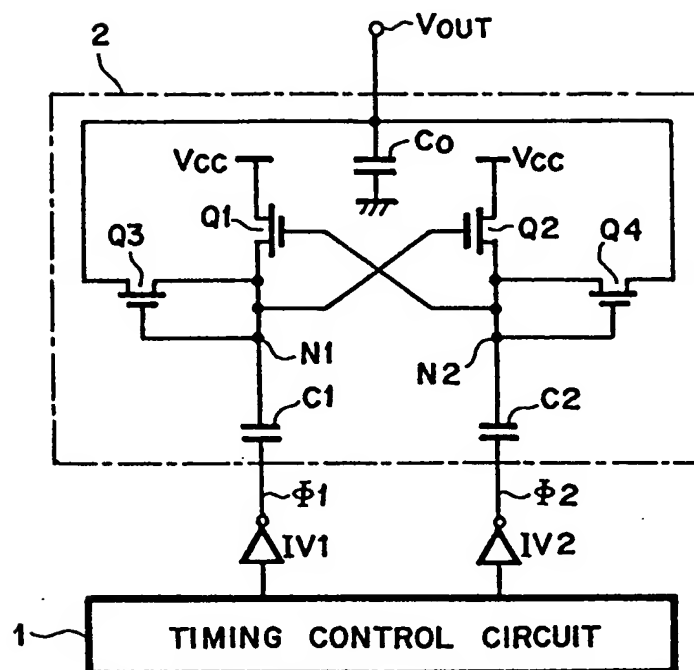
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FIG. 1A  
PRIOR ART



**FIG. 1B**  
**PRIOR ART**

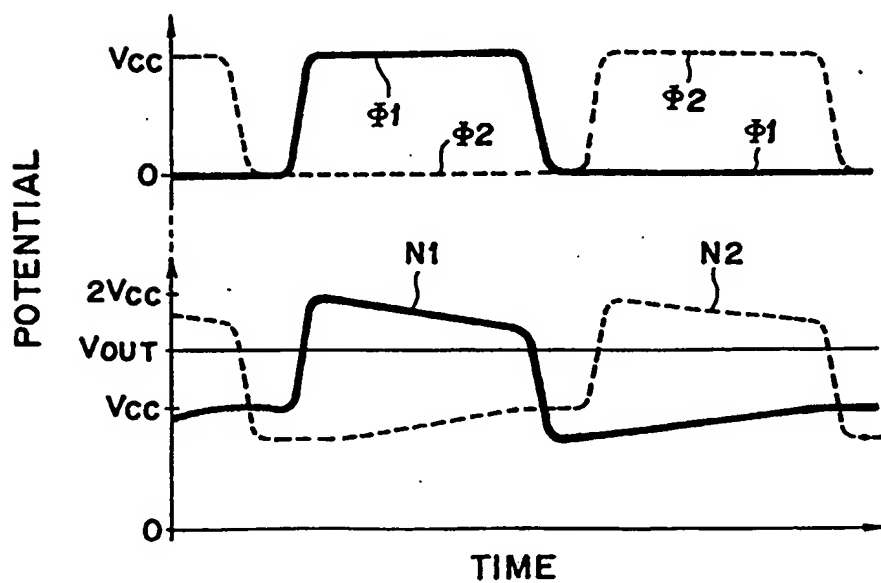




FIG. 2A

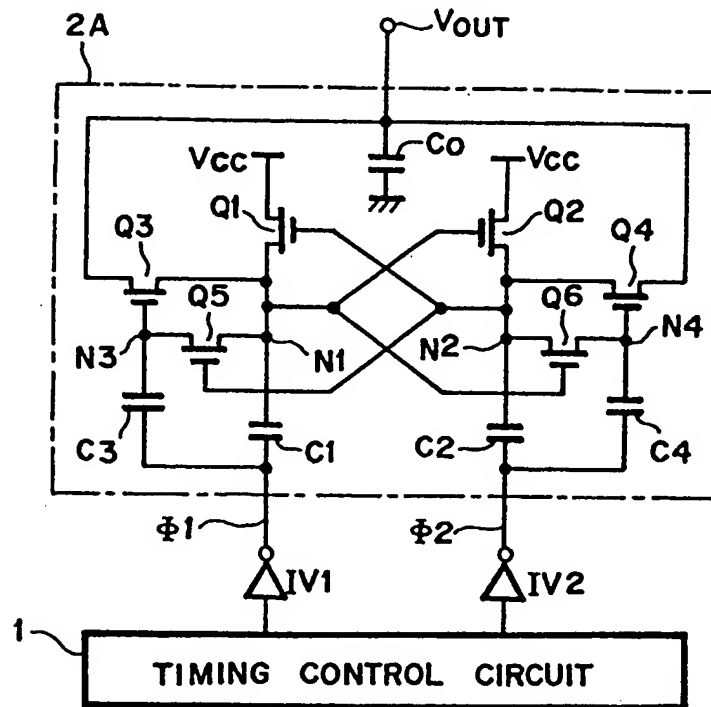


FIG. 2B

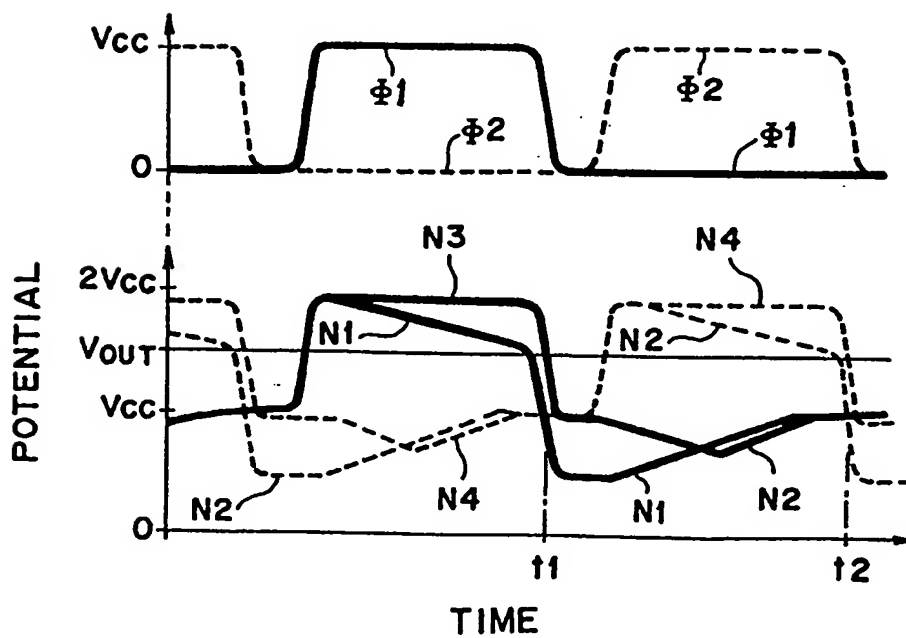
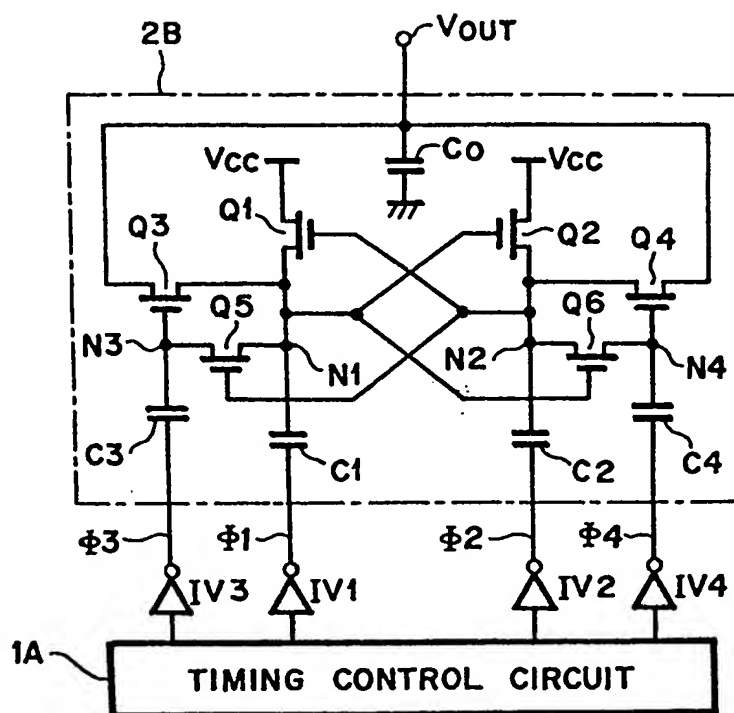


FIG. 3A



**FIG. 3B**

